User Guide for

FEBFL7730_L20L008B

Dimmable LED Bulb at Low Line

Featured Fairchild Product:

FL7730

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

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This FEBFL7730_L20L008B Evalution Board can be identified by the silkscreen marking FL7730 Low Line on the top side of the pcb. This user guide supports the evaluation board for the FL7730, FEBFL7730_L20L008B. This kit supersedes the FEBFL7730_L20L008A. The revised kit incorporates the next generation FL7730, which is redesigned for improved dimming performance. It should be used in conjunction with the FL7730 datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com or the evaluation board page http://www.fairchildsemi.com/products/evaluationboards/.

1. Introduction

This document describes the proposed solution for low-line voltage LED ballast using the FL7730 Primary-Side Regulator (PSR) single-stage controller. The input voltage range is $90V_{RMS}$ – $140V_{RMS}$ and there is one DC output with a constant current of 380mA at $22V_{NOMINAL}$. This document contains general description of FL7730, the power supply specification, schematic, bill of materials, and the typical operating characteristics.

1.1. General Description

The FL7730 is an active Power Factor Correction (PFC) controller using single-stage flyback topology. Dimming control with no flicker is implemented by an analog sensing method. Primary-side regulation and single-stage topology reduce external components such as input bulk capacitor and feedback circuitry and minimize cost. To improve good power factor and Total Harmonic Distortion (THD), constant on-time control is utilized with internal error amplifier and a low-bandwidth compensator. Precise constant-current control regulates accurate output current, independent of input voltage and output voltage. Operating frequency is proportionally changed by output voltage to guarantee DCM operation with higher efficiency. FL7730 provides protections such as open-LED, short-LED, and over-temperature protection.

1.2. Features

- Compatible with Traditional TRIAC Control
- Cost-Effective Solution without Input Bulk Capacitor and Feedback Circuitry
- Power Factor Correction (PFC)
- Accurate Constant-Current (CC) Control
- Line Voltage Compensation for CC Control
- Linear Frequency Control for Better Efficiency and Simpler Design
- Open-LED Protection
- Short-LED Protection
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection with Auto Restart
- Low Startup Current: 20μA
- Low Operating Current: 5mA
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- SOP-8 Package Available

1.3. Internal Block Diagram

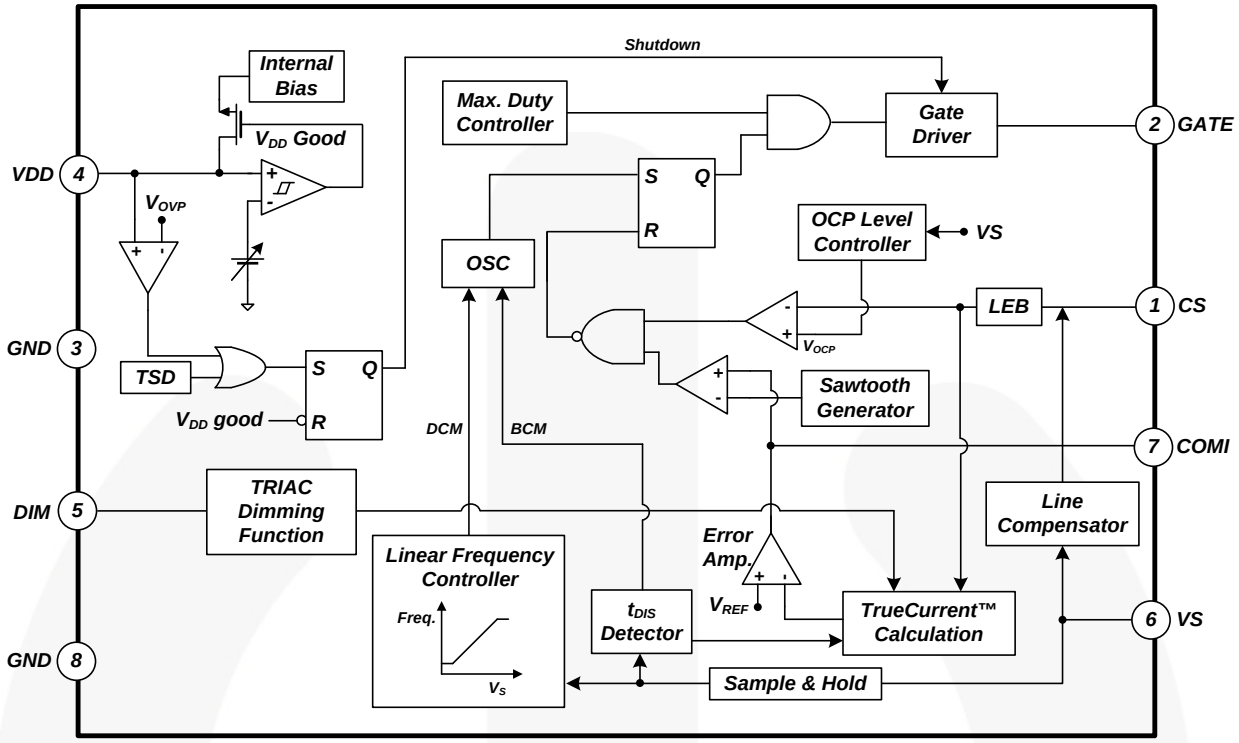

Figure 1. Internal Block Diagram

2. General Specifications

All data in Table 1 was measured at an ambient temperature of 25°C.

Table 1. Summary of Features and Performance for LED Lighting Bulb

Description	Symbol	Value	Comments
Input Voltage	$V_{IN,MIN}$	90V	Minimum Input Voltage
	$V_{IN,MAX}$	140V	Maximum Input Voltage
	$V_{IN,NOMINAL}$	110~120V	Nominal Input Voltage
Input Frequency	f_{IN}	50-60Hz	Line Frequency
Output Voltage Current	$V_{OUT,MIN}$	10V	Minimum Output Voltage
	$V_{OUT,MAX}$	28V	Maximum Output Voltage
	$V_{OUT,NOMINAL}$	22V	Nominal Output Voltage
	$I_{OUT,NOMINAL}$	380mA	Nominal Output Current
	$I_{OUT,RIPPLE}$	±65mA	Output Current Ripple
	CC Deviation	<±3.9%	Line Input Voltage Change:90~140V_{AC}
		<±2.1%	Output Voltage Change:10~28V
Efficiency	**Note: No Dimmer Connected**		
	Eff_{90VAC}	80.7%	Efficiency at 90V_{AC} Line Input Voltage
	Eff_{110VAC}	82.2%	Efficiency at 110V_{AC} Line Input Voltage
	Eff_{120VAC}	82.5%	Efficiency at 120V_{AC} Line Input Voltage
	Eff_{140VAC}	82.9%	Efficiency at 140V_{AC} Line Input Voltage
PF / THD	**Note: No Dimmer Connected**		
	PF / THD_{90VAC}	0.98 / 7.4%	PF / THD at 90V_{AC} Line Input Voltage
	PF / THD_{110VAC}	0.96 / 9.5%	PF / THD at 110V_{AC} Line Input Voltage
	PF / THD_{120VAC}	0.95 / 10.4%	PF / THD at 120V_{AC} Line Input Voltage
	PF / THD_{140VAC}	0.91 / 12.4%	PF / THD at 140 V_{AC} Line Input Voltage
Temperature	**Note: Open-Frame Condition (T_A=25°C)**		
	T_{FL7730}	50ºC	FL7730 Temperature
	T_{MOSFET}	53ºC	Primary MOSFET Temperature
	T_{DIODE}	47ºC	Secondary Diode Temperature
	$T_{TRANSFORMER}$	52ºC	Transformer Temperature
	T_{DAMPER}	57ºC	Active Damper Temperature
	$T_{STR.RESISTOR}$	56ºC	Startup Resistor Temperature

3. Photographs

Figure 2. Top View of Evaluation Board

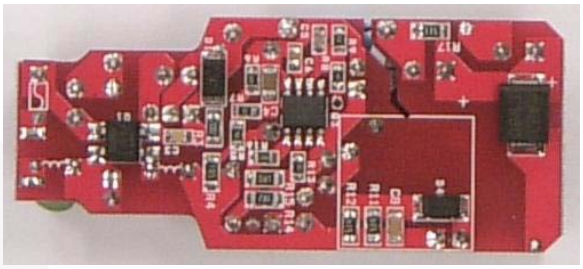

Figure 3. Bottom View of Evaluation Board

Dimensions: 62.5mm (L) × 26.8mm (W) × 12.0 (H)

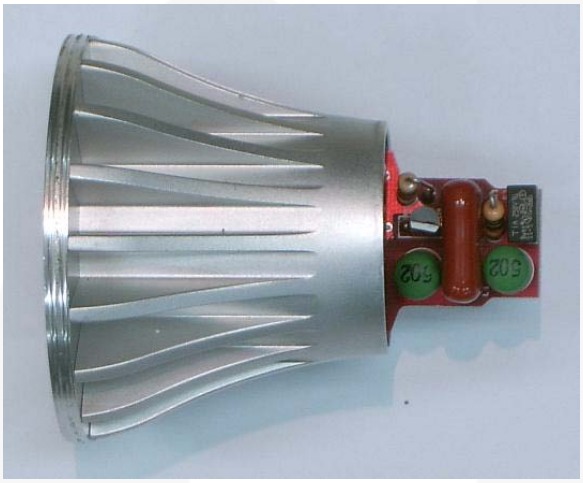

Figure 4. Side View in Bulb Case Type 1

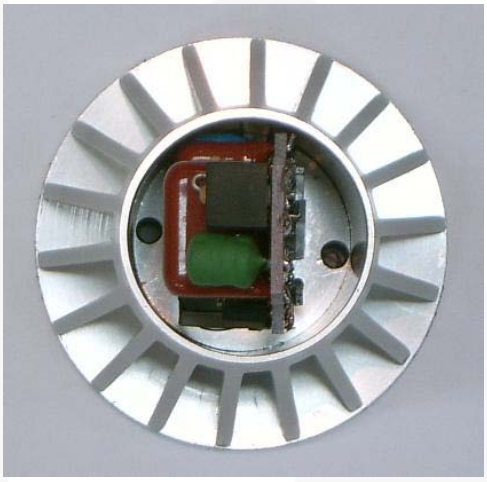

Figure 5. Bottom View in Bulb Case Type 1

Bulb Case Type 1 : 32mm (Case Diameter) × 40mm (Case Depth)

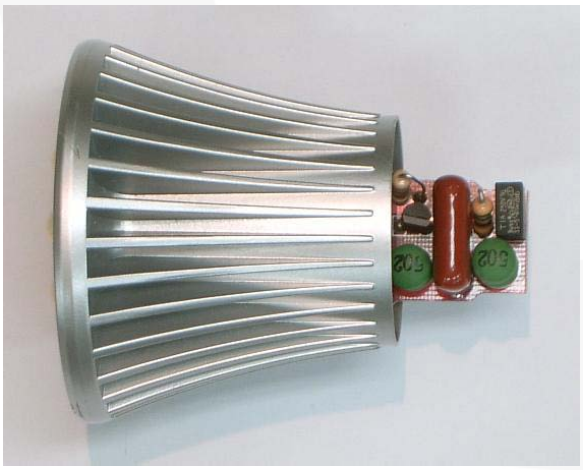

Figure 6. Side View in Bulb Case Type 2

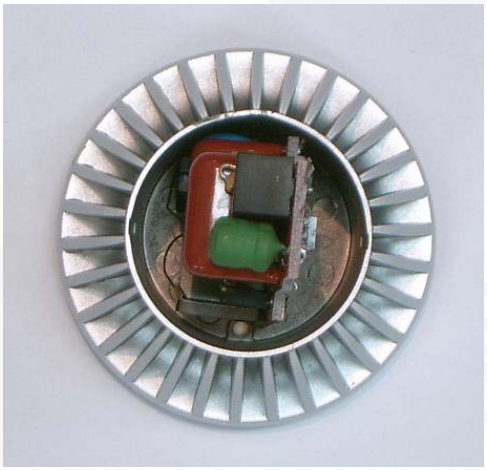

Figure 7. Bottom View in Bulb Case Type 2

Bulb Case Type 2 : 34mm (Case Diameter) × 44mm (Case Depth)

4. Printed Circuit Board

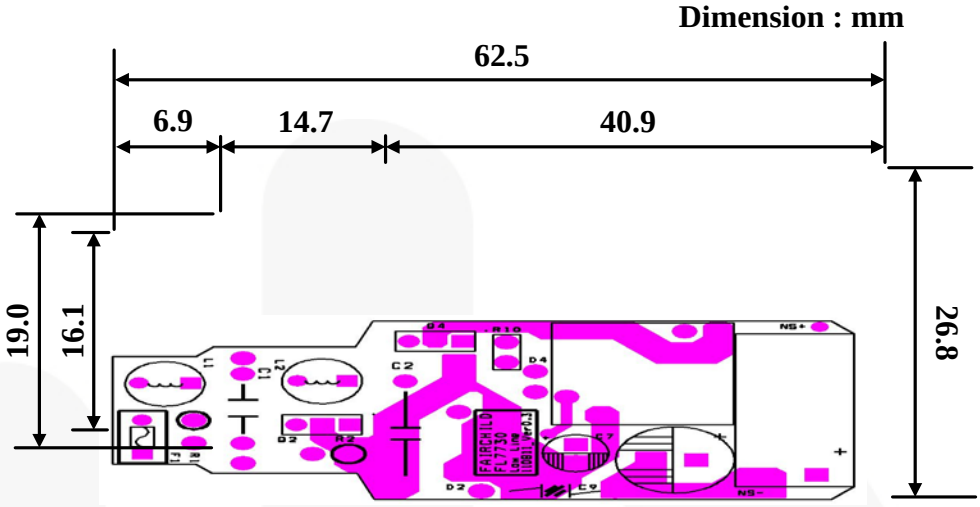

Figure 8. Printed PCB, Top Side

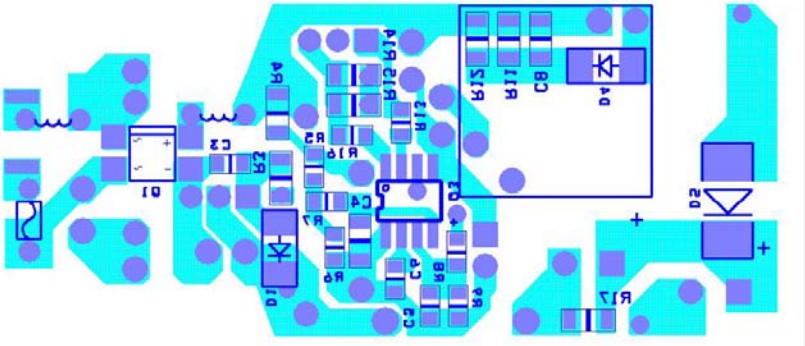

Figure 9. Printed PCB, Bottom Side

5. Schematic

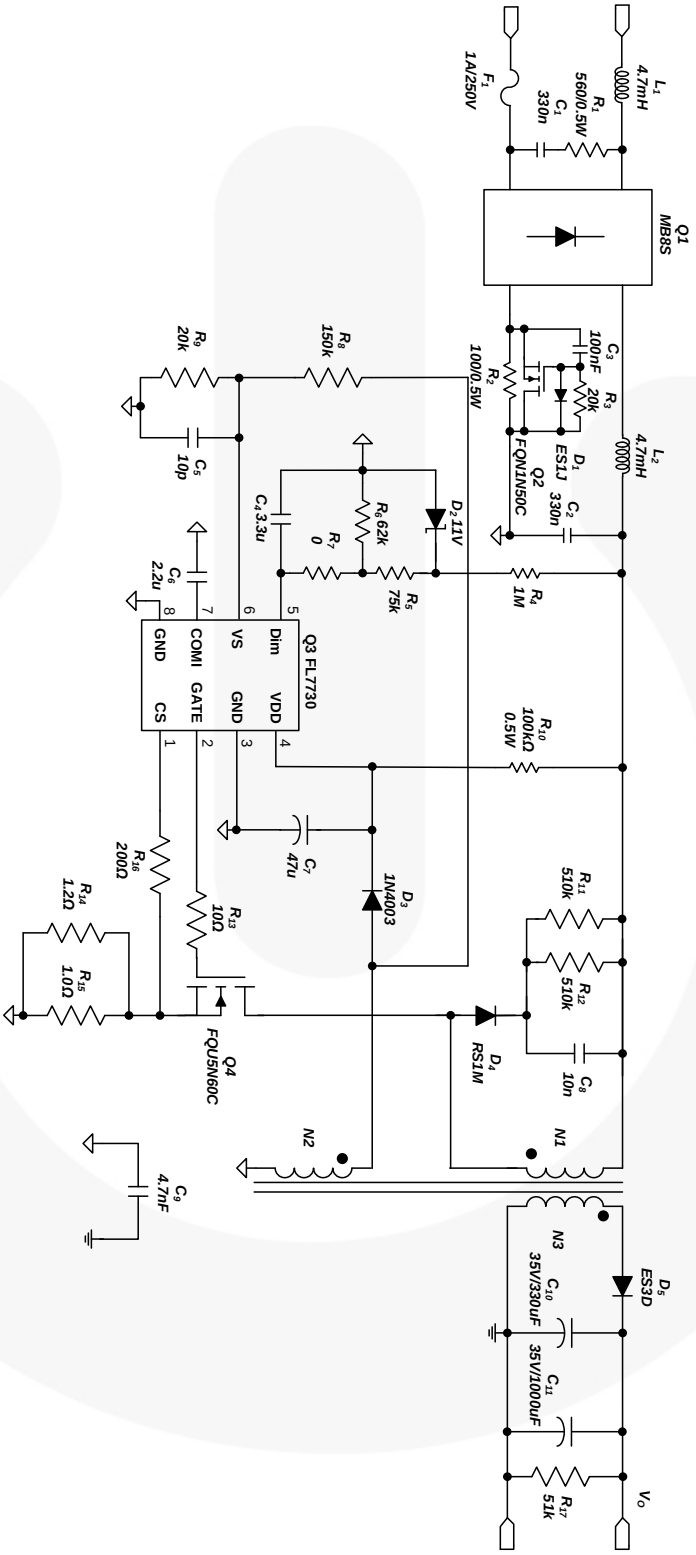

Figure 10. Schematic of Evaluation Board

6. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	Q1	MB8S	1	Bridge Diode	Fairchild Semiconductor
2	Q2	FQN1N50C	1	1A / 500V Active Damper MOSFET	Fairchild Semiconductor
3	Q3	FL7730MY_F116	1	Main Controller	Fairchild Semiconductor
4	Q4	FQU5N60C	1	5A / 600V Main Switch	Fairchild Semiconductor
5	F1	SS-5-1A	1	1A / 250V Fuse	Bussmann
6	L1, L2	R06472KT00	2	4.7mH Filter Inductor	Bosung
7	D1	ES1J	1	1A / 600V Diode	Fairchild Semiconductor
8	D2	1N5241	1	11V Zener Diode	Fairchild Semiconductor
9	D3	1N4003	1	1A / 200V Diode	Fairchild Semiconductor
10	D4	RS1M	1	1A / 1000V Diode	Fairchild Semiconductor
11	D5	ES3D	1	3A / 200V Fast Rectifier	Fairchild Semiconductor
12	C1, C2	MPE 400V334K 14S	1	330nF / 400V Film Capacitor	Sungho
13	C3	C0805C104K3RACTU	1	100nF / 25V SMD Capacitor 2012	Kemet
14	C4	C1206C335K3PACTU	1	3.3µF / 25V SMD Capacitor 3216	Kemet
15	C5	C0805C100M3GACTU	1	10pF / 25V SMD Capacitor 2012	Kemet
16	C6	C2012Y5V1E225Z	1	2.2µF / 25V SMD Capacitor 2012	TDK
17	C7	KMG 47µF / 35V	1	47µF / 35V Electrolytic Capacitor	Samyoung
18	C8	C1206C103KDRACTU	1	10nF / 1kV SMD Capacitor 3216	Kemet
19	C9	SCFz2E472M10BW	1	4.7nF / 250V Y-Capacitor	Samwha
20	C10	KMG 330µF / 35V	1	330µF / 35V Electrolytic Capacitor	Samyoung
21	C11	RM 1000µF / 35V	1	1000µF / 35V Electrolytic Capacitor	Samwha
22	R1	SR03700005600KR500	1	560Ω / 0.5W Metal Resistor	Vishay
23	R2	RNF12JTD100R	1	100Ω / 0.5W Metal Resistor	Stackpole Electrical
24	R3	RC1206JR-0720KL	1	20kΩ SMD Resistor 3216	Yageo
25	R4	RC1206JR-071ML	1	1MΩ SMD Resistor 3216	Yageo
26	R5	RC0805JR-0775KL	1	75kΩ SMD Resistor 2012	Yageo
27	R6	RC0805JR-0762KL	1	62kΩ SMD Resistor 2012	Yageo
28	R7	RC0805JR-070R0L	1	0Ω SMD Resistor 2012	Yageo
29	R8	RC0805JR-07150KL	1	150kΩ SMD Resistor 2012	Yageo
30	R9	RC0805JR-0720KL	1	20kΩ SMD Resistor 2012	Yageo
31	R10	RNF12GTD100K	1	100kΩ / 0.5W Metal Resistor	Stackpole Electrical
32	R11, R12	RC1206JR-07510KL	2	510kΩ SMD Resistor 3216	Yageo
33	R13	RC0805JR-0710RL	1	10Ω SMD Resistor 2012	Yageo

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Bill of Materials (Continued)

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
34	R14	RC1206JR-071R2L	1	1.2Ω SMD Resistor 3216	Yageo
35	R15	RC1206FR-071RL	1	1.0Ω SMD Resistor 3216	Yageo
36	R16	RC0805JR-07200RL	1	200Ω SMD Resistor 2012	Yageo
37	R17	RC1206JR-0751KL	1	51kΩ SMD Resistor 3216	Yageo

7. Transformer and Winding Specifications

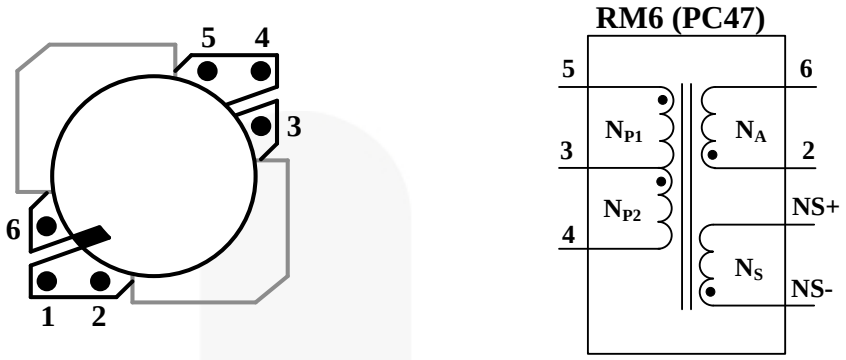

Figure 11. Transformer Specifications & Construction

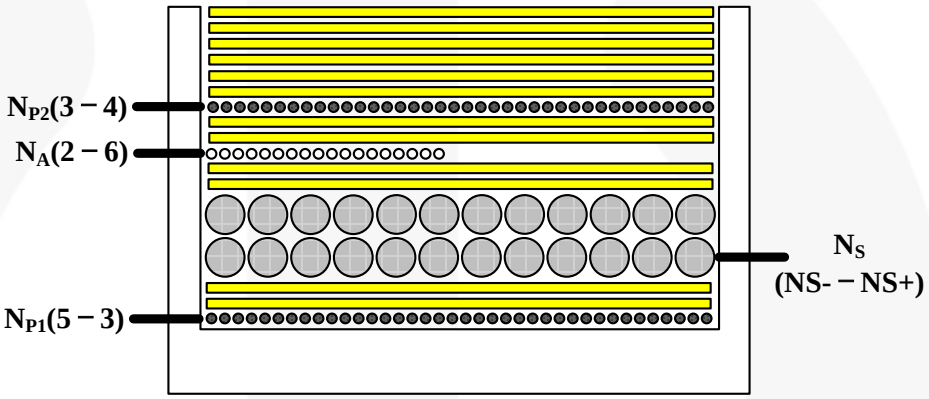

Figure 12. Transformer Winding Structure

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	5 → 3	0.13φ	38 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025mm, 2-Layer				
3	N_S	NS- → NS+	0.3φ (TIW)	24 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025mm, 2-Layer				
5	N_A	2 → 6	0.13φ	18 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025mm, 2-Layer				
7	N_{P2}	3 → 4	0.13φ	38 Ts	Solenoid Winding
8	Insulation : Polyester Tape t = 0.025mm, 6-Layer				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	1 – 2	1mH ±10%	50kHz, 1V
Leakage	1 – 2	8μH	50kHz, 1V Short All Output Pins

8. Performance of Evaluation Board

8.1. Startup

Startup time is 0.8s. There is no overshoot at output current and voltage in startup sequence (*refer I_{OUT} and V_{DD} waveform. V_{DD} indicates a reflected output voltage*).

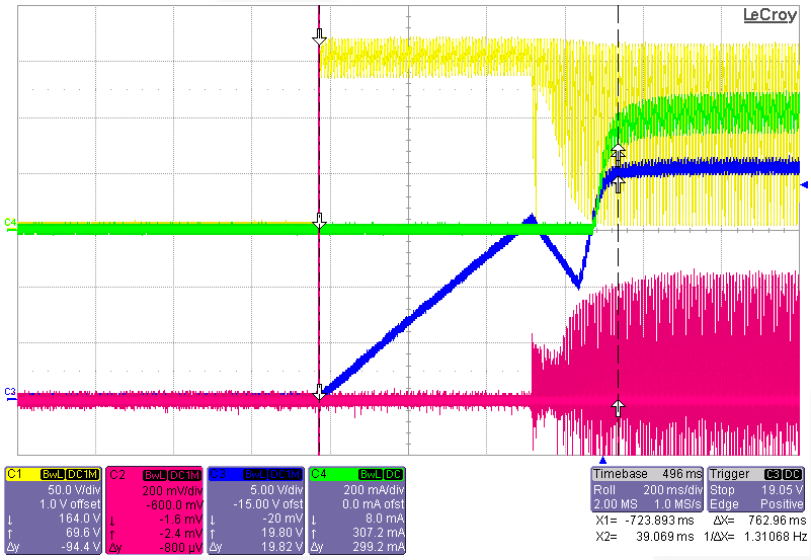
LeCroy
C1 50.0 V/div 1.0 V offset 164.0 V 69.6 V -94.4 V
C2 200 mV/div -600.0 mV -1.6 mV -2.4 mV -800 µV
C3 5.00 V/div -15.00 V ofst -20 mV 19.80 V 19.82 V
C4 200 mA/div 0.0 mA ofst 8.0 mA 307.2 mA 299.2 mA
Timebase 496 ms Roll 200 ms/div 2.00 MS 1.0 MS/s
Trigger Stop 19.05 V Edge Positive
X1= -723.893 ms ΔX= 762.96 ms
X2= 39.069 ms 1/ΔX= 1.31068 Hz

Figure 13. Startup – V_{IN} [110V_{AC}], C1 [V_{IN}], C2 [V_{CS}] C3 [V_{DD}], C4,[I_{OUT}], (No Dimmer Connected)

8.2. Operation Waveforms

In steady state, line compensation regulates output current regardless of input voltage variations. Output current ripple is ±65mA with a rated output current of 380mA.

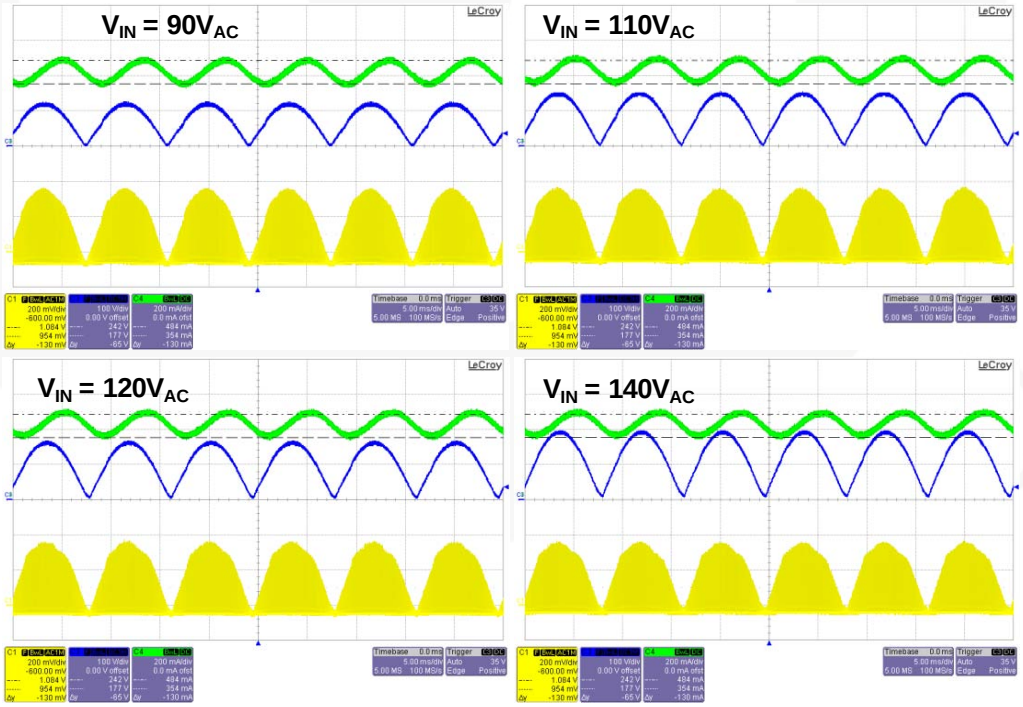

Figure 14. Operation Waveforms – V_O [22V], I_O [380mA], C1 [V_{CS}], C3, [V_{IN}], C4 [I_{OUT}]

8.3. Constant Current Regulation

Constant current deviation in the output voltage range from 10V to 28V is less than 2.1% at each line input voltage. Line regulation at the rated output voltage (22V) is less than 3.9%.

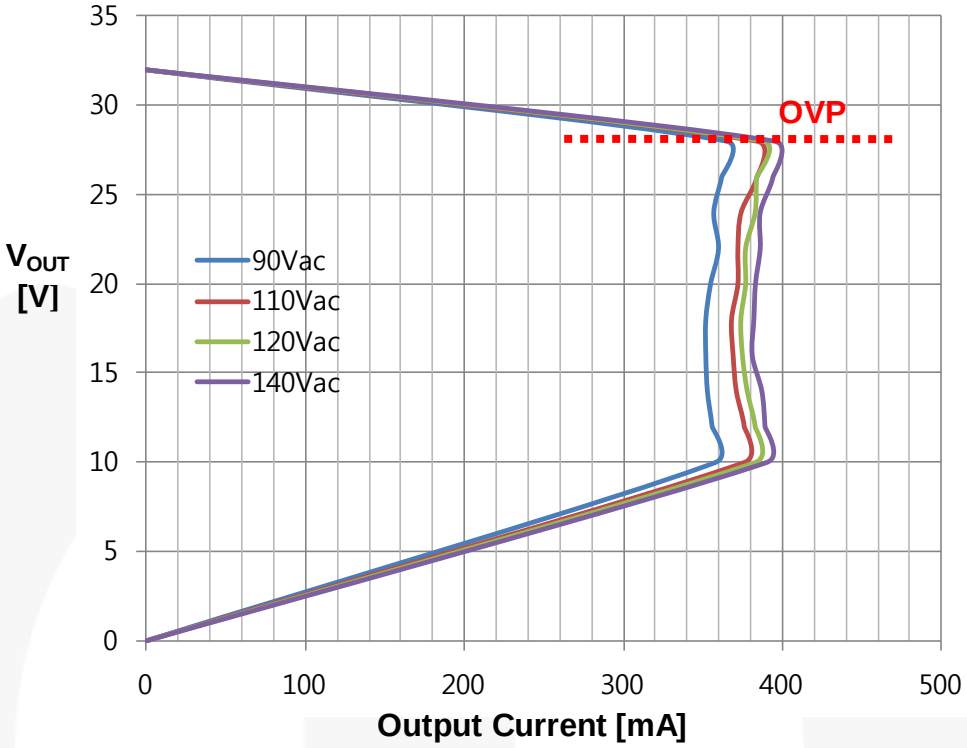

Figure 15. Constant Current Regulation – Measured by E-Load [CR Mode]

Table 4. Constant Current Regulation by Output Voltage Change (10~28V)

Input Voltage	Min. Current	Max. Current	Tolerance
$90V_{AC}$ / 60Hz	352mA	365mA	±1.8%
$110V_{AC}$ / 60Hz	368mA	384mA	±2.1%
$120V_{AC}$ / 60Hz	374mA	388mA	±1.8%
$140V_{AC}$ / 60Hz	381mA	395mA	±1.8%

Table 5. Constant Current Regulation by Line Voltage Change (90~140V_{AC})

Output Voltage	$90V_{AC}$	$110V_{AC}$	$120V_{AC}$	$140V_{AC}$	Tolerance
20V	355mA	372mA	377mA	383mA	±3.8%
22V	360mA	372mA	377mA	386mA	±3.5%
24V	357mA	374mA	383mA	386mA	±3.9%

8.4. Open/Short-LED Protections

In short-LED condition, the OCP level is reduced from 0.7V to 0.2V because the FL7730 lowers the OCP level when V_S voltage is less than 0.4V during output diode conduction time. The output current in the short-LED condition is less than 1.5A, which doesn't damage any external components.

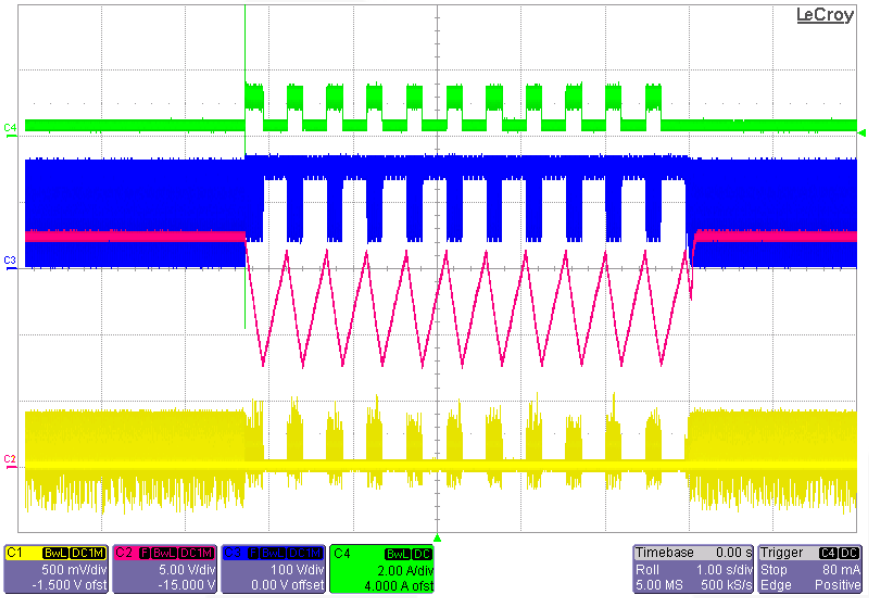
LeCroy
C4
C3
C2
C1 BwL DC1M 500 mV/div -1.500 V ofst
C2 F BwL DC1M 5.00 V/div -15.000 V
C3 F BwL DC1M 100 V/div 0.00 V offset
C4 BwL DC 2.00 A/div 4.000 A ofst
Timebase 0.00 s Roll 1.00 s/div 5.00 MS 500 kS/s
Trigger C4 DC Stop 80 mA Edge Positive

Figure 16. Short-LED Condition – V_{IN} [110V_{AC}], C1 [V_{CS}], C2 [V_{DD}], C3 [V_{IN}], C4 [I_{OUT}]

In open-LED condition, output voltage is limited around 32V by OVP in V_{DD}. The output over-voltage protection level can be controlled by turn ratio of auxiliary and secondary windings.

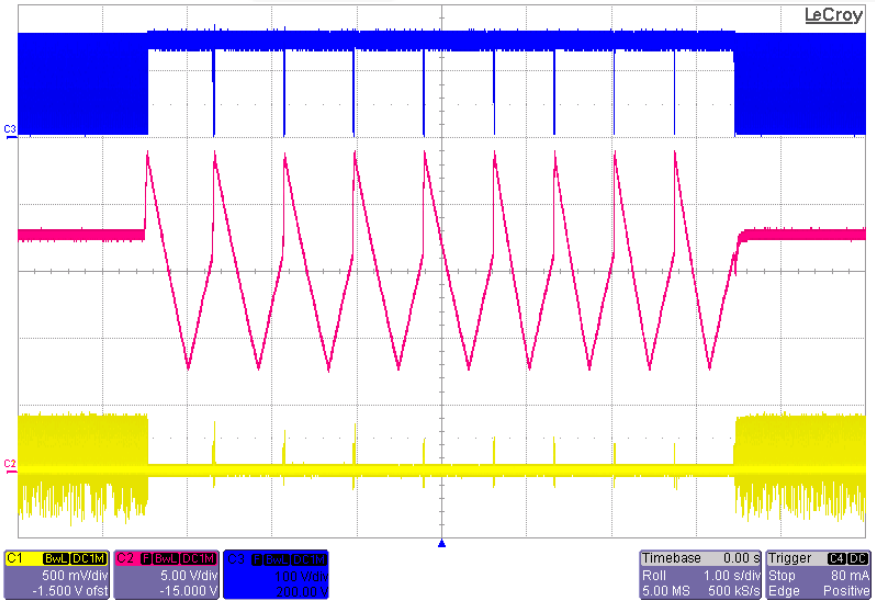
LeCroy
C3
C2
C1 BwL DC1M 500 mV/div -1.500 V ofst
C2 F BwL DC1M 5.00 V/div -15.000 V
C3 F BwL DC1M 100 V/div 200.00 V
Timebase 0.00 s Roll 1.00 s/div 5.00 MS 500 kS/s
Trigger C4 DC Stop 80 mA Edge Positive

Figure 17. Open-LED Condition – V_{IN} [110V_{AC}], C1 [V_{CS}], C2 [V_{DD}], C3 [V_{IN}]

8.5. Dimming Operation

Dimming operation waveforms are shown in Figure 18 - Figure 20. Active damper, RC bleeder, and dimming control in FL7730 implement flicker-free dimming operation. Spike current at dimmer firing is less than 1.2A.

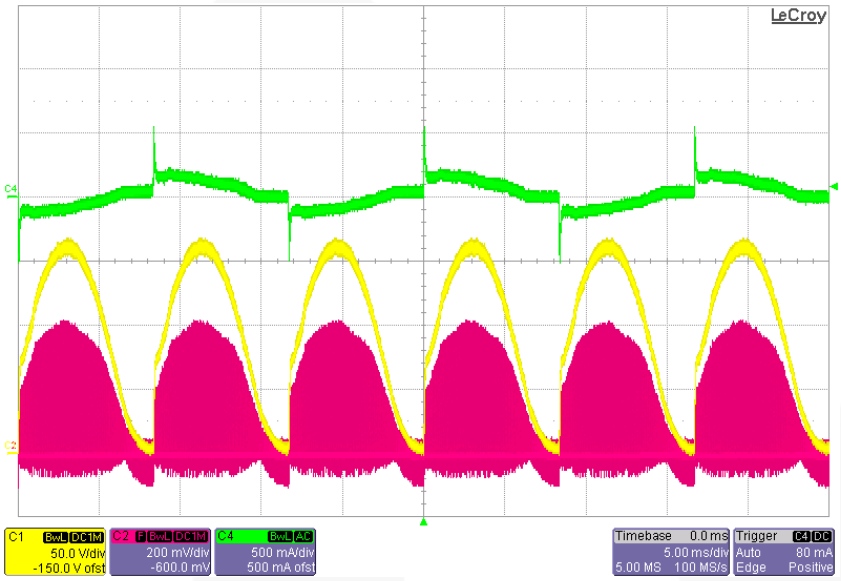

Figure 18. Dimming Operation Waveforms: Max. Dimming Angle, V_{IN} [120V_{AC}], C1 [V_{IN}], C2 [V_{CS}], C4 [I_{IN}]

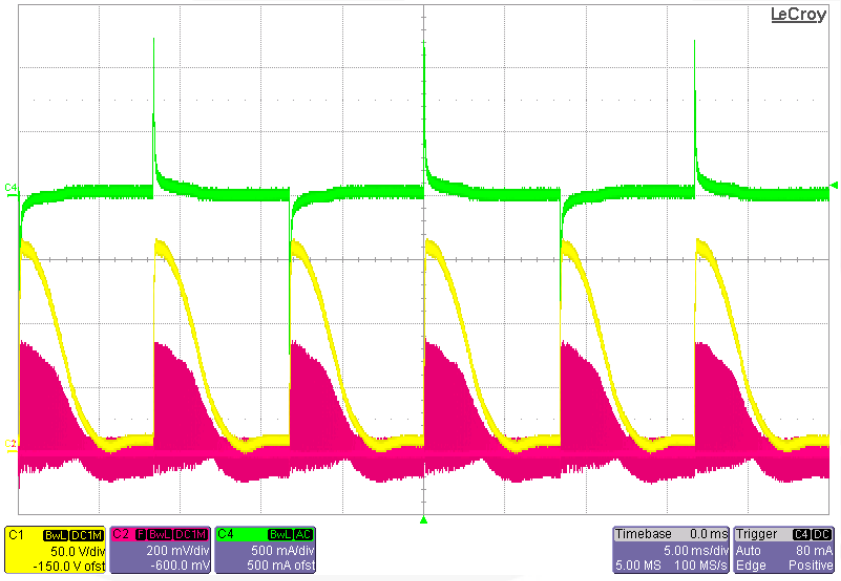

Figure 19. Dimming Operation Waveforms: 90º Dimming Angle, V_{IN} [120V_{AC}] ,C1 [V_{IN}], C2 [V_{CS}], C4 [I_{IN}]

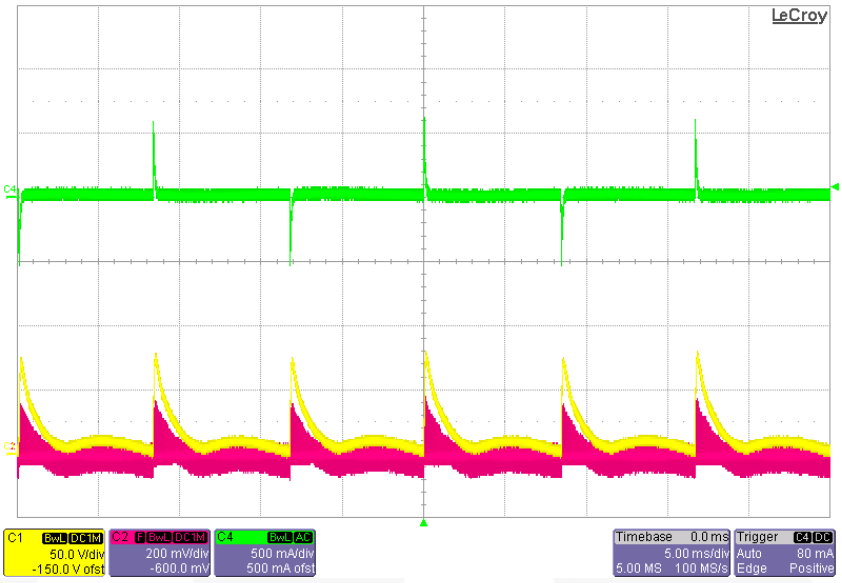
LeCroy
C1 BwL DC1M 50.0 V/div -150.0 V ofst
C2 BwL DC1M 200 mV/div -600.0 mV
C4 BwL AC 500 mA/div 500 mA ofst
Timebase 0.0 ms 5.00 ms/div 5.00 MS 100 MS/s
Trigger C4 DC Auto 80 mA Edge Positive

Figure 20. Dimming Operation Waveforms – Min. Dimming Angle, V_{IN} [120V_{AC}], C1 [V_{IN}], C2 [V_{CS}], C4 [I_{IN}]

Output current is controlled by dimming function when rotating dimmer switch as in the dimming curve in Figure 21. The dimming control block in FL7730 smoothly changes regulated output current by detecting dimming angle.

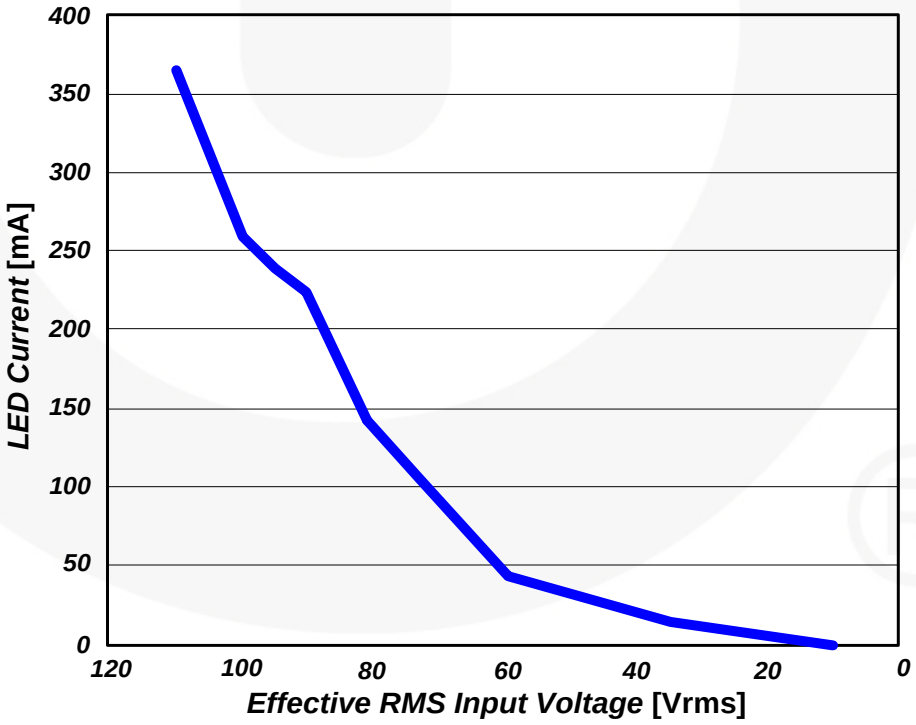

Figure 21. Dimming Curve (Effective RMS Input Voltage vs. Output Current) – Line Voltage [120V_{AC}]

Table 6. TRIAC Dimmer Compatibility

Manufacturer	Dimmer	Condition	Maximum Current	Minimum Current	Flicker
LUTRON	S-600P-WH	120V / 60Hz	330mA	40mA (12%)	No
LUTRON	CN-600P-WH	120V / 60Hz	328mA	11mA (3%)	No
LUTRON	GL-600H	120V / 60Hz	365mA	8mA (2%)	No
LUTRON	TG-603PGH-WH	120V / 60Hz	252mA	12mA (5%)	No
LUTRON	TG-600PH-WH	120V / 60Hz	333mA	14mA (4%)	No
LUTRON	LG-600P	120V / 60Hz	327mA	3mA (1%)	No
LUTRON	CTCL-153PD	120V / 60Hz	320mA	58mA (18%)	No
LUTRON	S-600-WH	120V / 60Hz	324mA	0mA (0%)	No
LUTRON	DV-600P-WH	120V / 60Hz	323mA	0mA (0%)	No
LUTRON	DV-603PG-WH	120V / 60Hz	260mA	3mA (1%)	No
LUTRON	DV-10P	120V / 60Hz	334mA	28mA (8%)	No
LUTRON	DVLV-600P	120V / 60Hz	316mA	4mA (1%)	No
LUTRON	AY-600P-WH	120V / 60Hz	329mA	8mA (2%)	No
LUTRON	D-600PH-DK	120V / 60Hz	309mA	0mA (0%)	No
LUTRON	Q-600P-WH	120V / 60Hz	333mA	21mA (6%)	No
LUTRON	SLV-600P	120V / 60Hz	330mA	7mA (2%)	No
LUTRON	GLT05	120V / 60Hz	316mA	22mA (7%)	No
LEVITON	6633-PL	120V / 60Hz	383mA	11mA (3%)	No
LEVITON	6683	120V / 60Hz	384mA	0mA (0%)	No
LEVITON	IP106	120V / 60Hz	380mA	36mA (9.5%)	No
LEVITON	1C4005	120V / 60Hz	344mA	0mA (0%)	No
LEVITON	6631-LW	120V / 60Hz	340mA	0mA (0%)	No
Legrand	F 165H	120V / 60Hz	344mA	3mA (0.9%)	No

The FL7703 Low-Line Evaluation Board demonstrates good dimmer compatibility without flicker. Minimum LED current is less than 5% for most dimmers.

8.6. System Efficiency

Power efficiency is 80.7 ~ 82.9% in 90 ~ 140V_{AC} input voltage range.

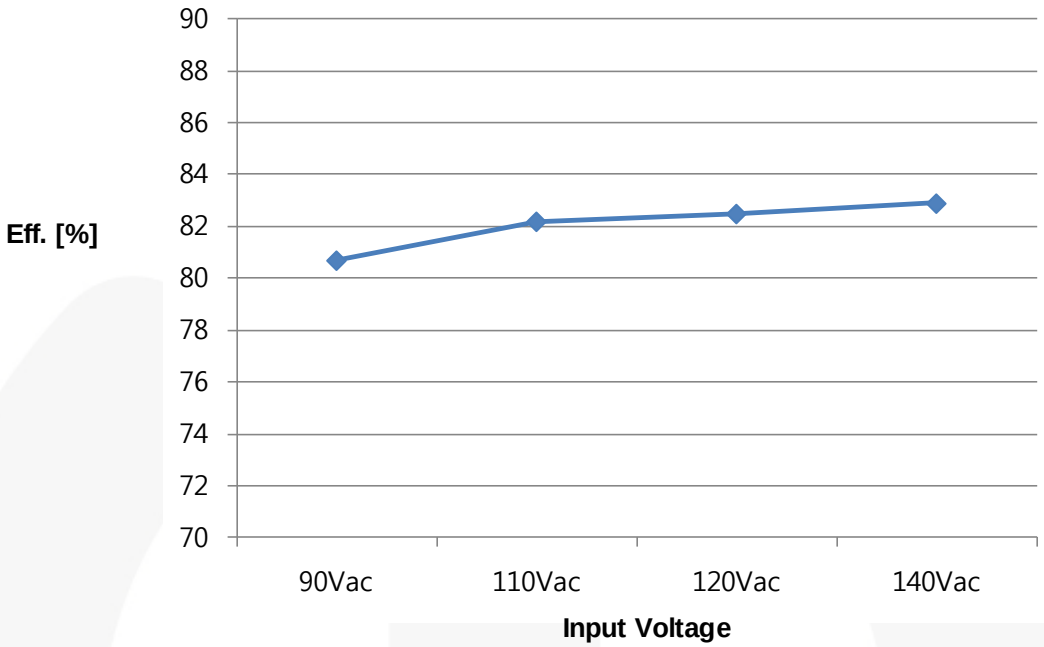

Figure 22. Power Efficiency (Input Voltage vs. Efficiency)

Table 7. System Efficiency

Input Voltage	Input Power	Output Current	Output Voltage	Output Power	Efficiency
90V_{AC}	9.68W	360mA	21.70V	7.81W	80.7%
110V_{AC}	9.96W	376mA	21.77V	8.19W	82.2%
120V_{AC}	10.02W	380mA	21.77V	8.27W	82.5%
140V_{AC}	10.15W	386mA	21.79V	8.41W	82.9%

8.7. Power Factor and Total Harmonic Distortion

FL7730 shows excellent power factor and THD performance. Power factor is very high with enough margins from 0.9. THD is much less than 30% specification.

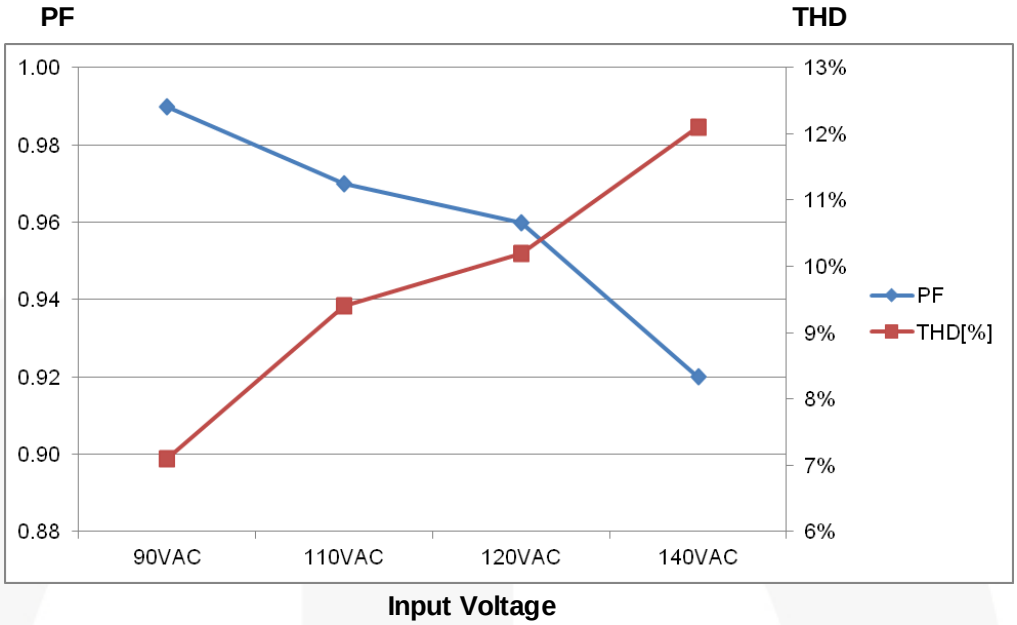

Figure 23. Power Factor & Total Harmonic Distortion (50Hz)

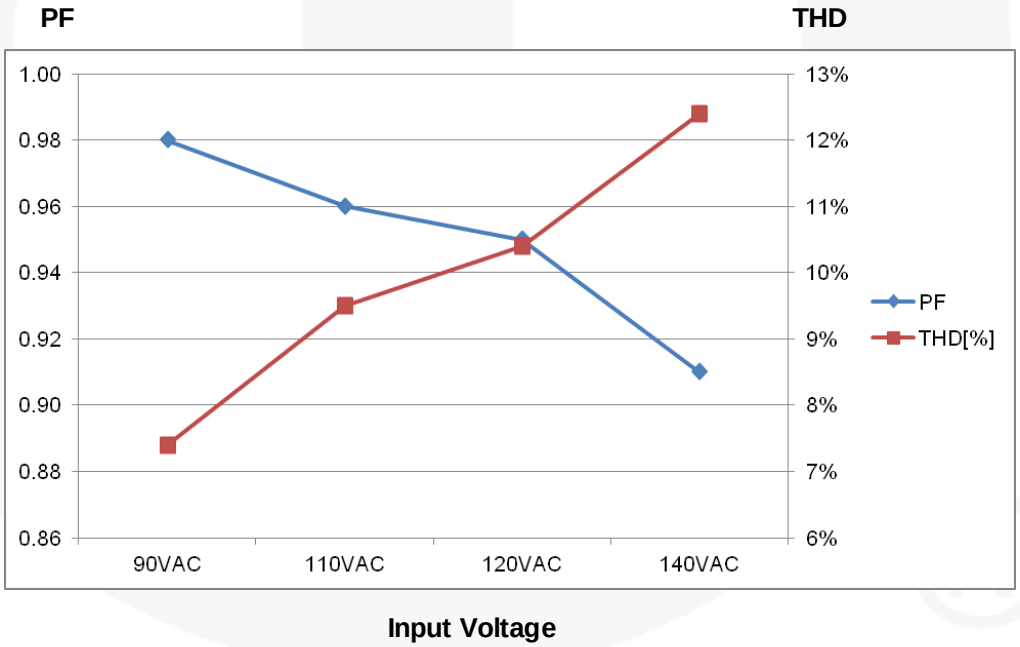

Figure 24. Power Factor & Total Harmonic Distortion (60Hz)

Table 8. Power Factor and Total Harmonic Distortion

Input Voltage	Output Current	Output Voltage	Frequency	PF	THD
$90V_{AC}$	360mA	21.70V	50Hz	0.99	7.1%
			60Hz	0.98	7.4%
$110V_{AC}$	376mA	21.77V	50Hz	0.97	9.4%
			60Hz	0.96	9.5%
$120V_{AC}$	380mA	21.77V	50Hz	0.96	10.2%
			60Hz	0.95	10.4%
$140V_{AC}$	386mA	21.79V	50Hz	0.92	12.1%
			60Hz	0.91	12.4%

8.8. Operating Temperature

Temperature of all the components on this board is less than 60°C.

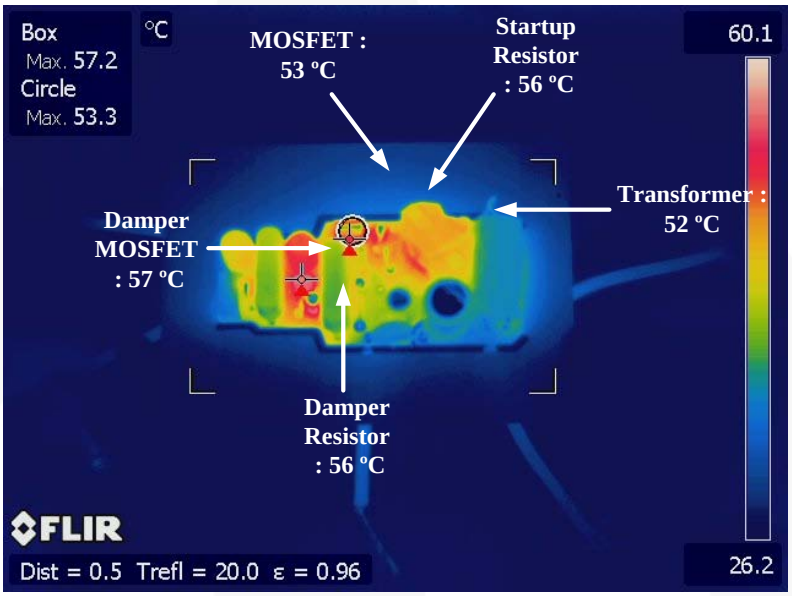

Figure 25. Board Temperature - Top View, V_{IN} [120V_{AC}], I_O [380mA]

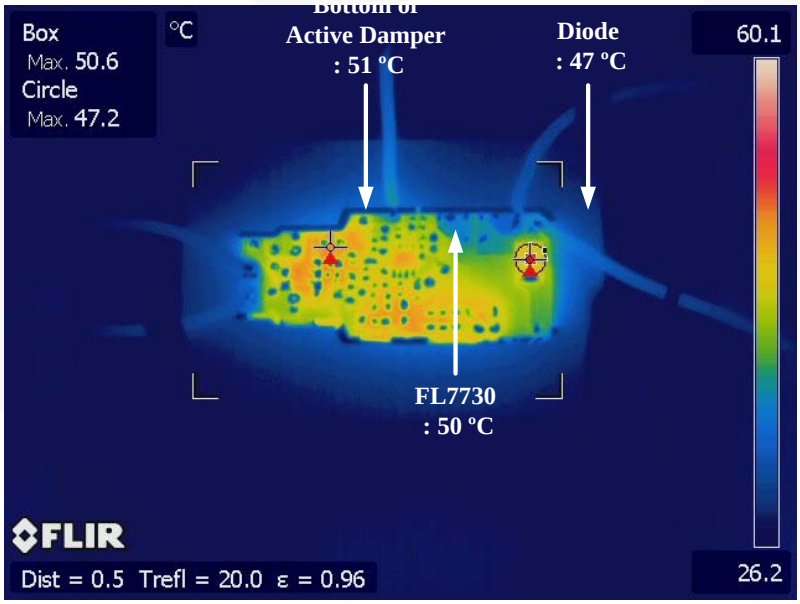

Figure 26. Board Temperature - Bottom View, V_{IN} [120V_{AC}], I_O [380mA]

8.9. Electromagnetic Interference (EMI)

The all measurement was conducted in observance of CISPR22 criteria.

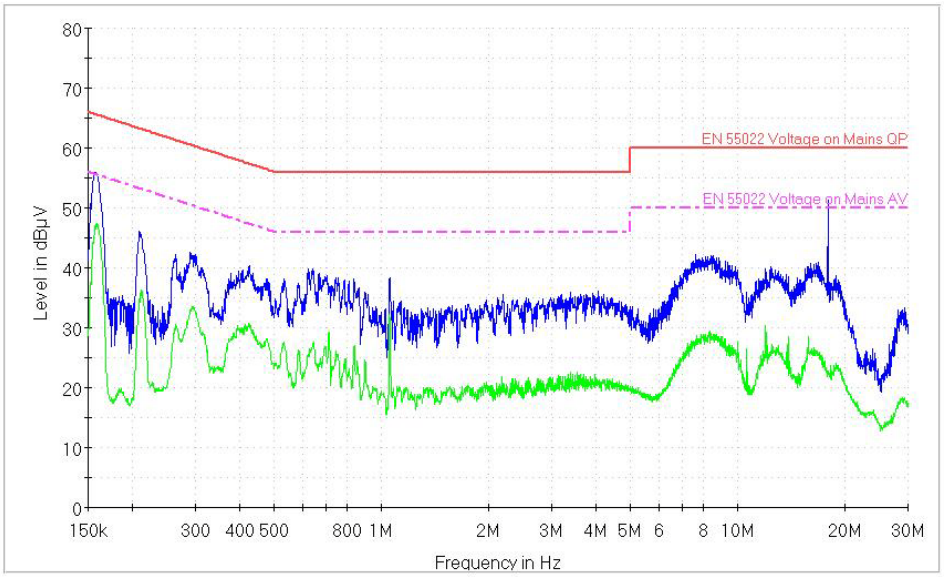

Figure 27. EMI Results – V_{IN} [110V], V_{OUT} [22V], I_{OUT} [380mA]

9. Revision History

Rev.	Date	Description
1.0.0.	Oct. 2011.	Initial Release
1.1.0	Jul. 2012.	Manufacturer & Part number are added in BOM FL7730 is changed to FL7730MY_F116 (no frequency hopping) Dimmer compatibility table is updated PF/THD at 50Hz is added EMI test result is updated
1.1.1	Aug. 2012.	Updating to match new naming conventions
1.1.2	Aug. 2013	Changed 22 V_{MAX} to 22 $V_{NOMINAL}$ in Introduction

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Replace components on the Evaluation Board only with those parts shown on the parts list (or Bill of Materials) in the Users' Guide. Contact an authorized Fairchild representative with any questions.

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